Hydrophones for Acoustic Exploration of the Extreme Depths of the Ocean

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LONG-TERM GOALS

Characterize the spatial and temporal statistics of the ambient noise field from the sea surface down to the greatest depths in the ocean.

OBJECTIVES

The objective of the deep ambient noise project is to develop and deploy a broadband (0.05 - 60 kHz), multi-sensor system capable of monitoring sound to the deepest depths (11,000 km) in the ocean. The system will return depth profiles of the noise spectral level and vertical coherence.

APPROACH

Two Vitrovex glass hemisperes of approximately 0.4 m internal diameter are used to form a complete sphere, which contains data acquisition and storage electronics. Throughputs connect external hydrophones and pressure/temperature sensors to the interior of the sphere. As the system descends into the ocean under the influence of gravity at a terminal speed of about 1 m/s, the broadband (0.05 - 60 kHz) ambient noise is detected on two hydrophones, separated vertically by about 0.5 m. At the lowest point in its descent, which may be as deep as 11,000 m, a drop weight is released via a burn wire, and the system returns to the surface under its own buoyancy. Recovery is achieved with the aid of an Argos antenna, an RF locator beacon and a high-intensity strobe light.

WORK COMPLETED

The data acquisition and storage electronics have been designed and fabricated. The circuits have been assembled into the Vitrovex sphere, along with pressure and temperature sensors. Several successful trial deployments have been made in the ocean to depths of about 1000 m using standard ITC hydrophones. New hydrophones, rated to depths of 7000m or greater, have recently been acquired and are currently being modified for integration into the deep ambient noise system. A set of recovery antennas has also been installed in the system. At-sea tests of the system to its maximum rated depth, which is in excess of 7000 m, are planned for later in the year.

RESULTS

Half a dozen trial deployments of the deep ambient noise system to a depth of about 1000 m in the ocean have been completely successful. To date, the system in all but one of these deployments has

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14. ABSTRACT
The objective of the deep ambient noise project is to develop and deploy a broadband (0.05 - 60 kHz), multi-sensor system capable of monitoring sound to the deepest depths (11,000 km) in the ocean. The system will return depth profiles of the noise spectral level and vertical coherence.

15. SUBJECT TERMS

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been tethered, as a precautionary measure in the event that the burn-wire weight-release were to fail. In fact, there were no failures, so finally the system was allowed to free-fall to 1000 m, where the descent terminated as planned, and it began its ascent back to the surface. Fig. 1 shows the recovery of the system after one of the tethered deployments. During the trial descents, ambient noise profiles were recorded on the two vertically separated ITC hydrophones over the frequency band from 0.01 to 60 kHz. Apart from a few minor problems in the first deployment from rubbing ropes, causing intermittent interference, the acoustic data are of good quality, giving us the noise spectral density and the vertical coherence as functions of depth and frequency. We are currently in the process of installing the new hydrophones with a depth rating of at least 7000 m.

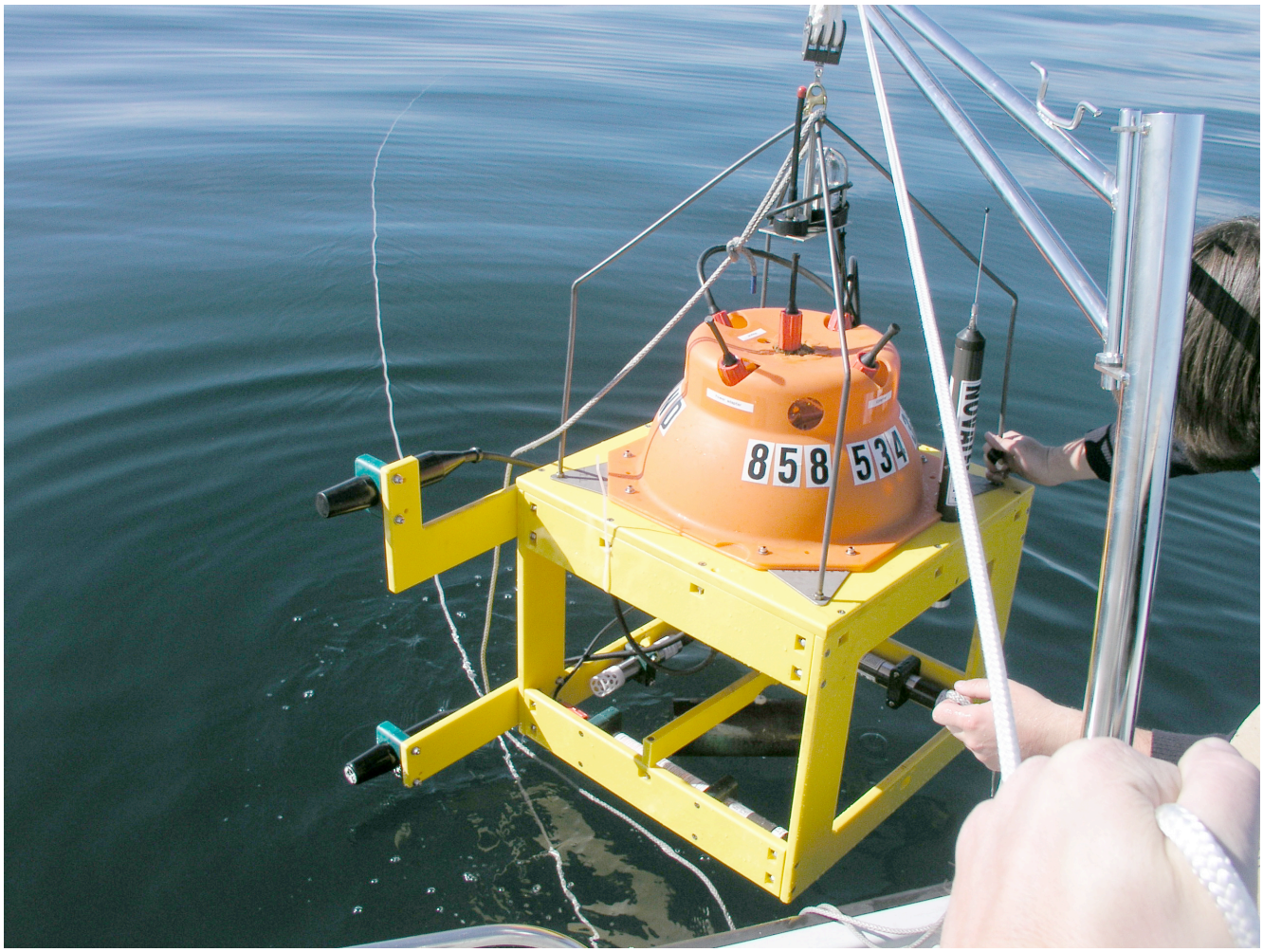

Fig. 1. Deep ambient noise system, complete with recovery antennas and two vertically separated ITC hydrophones. The Vitrovex sphere containing the data acquisition and storage electronics is inside the plastic orange casing.

IMPACT/APPLICATIONS

The depth capability of the deep ambient noise system opens up a number of potential applications, in addition to recording ambient noise. For example, the system could be used to investigate the acoustic properties of hydrothermal vents, which are typically found at depths around 5000 m, well below the performance limit of most hydrophones. Another interesting possibility is to exploit the steady descent and ascent rates to provide a synthetic aperture in the vertical. A synthetic vertical aperture of 1 km, say, could yield enhanced signal detection while remaining entirely covert.

TRANSITIONS

It is too early for a transition, since the deep ambient noise system was only recently conceived and is still under development.

RELATED PROJECTS

None at present.

PUBLICATIONS

Journal Articles & Chapters in Book

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2. M. J. Buckingham, "Sound waves and shear waves in marine sediments", seminar, California Institute of Technology, 30 October 2007 [INVITED].

3. M. J. Buckingham, "Wave propagation in sediments: strain hardening and the G-S dispersion relations", 8th International Conference on Theoretical and Computational Acoustics (ICTCA), FORTH, Heraklion, Crete, 2-5 July 2007.

4. M. J. Buckingham, "Inversions - a radical idea: information from ambient noise", Pacific Rim Underwater Acoustics Conference (PRUAC), Vancouver, Canada, pp. 1-2 [INVITED].

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on Underwater Acoustics Measurements: Technologies and Results, (Heraklion, Crete, Greece, 28 June - 1 July 2005) [INVITED].

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5. M. J. Buckingham, "Method and apparatus for measuring the speed and attenuation of sound", 28 November 2003, UCSD Ref. No. SD2004-080-1 [provisional application].

HONORS/AWARDS/PRIZES

1. M. J. Buckingham, Royal Aerospace Establishment, Clerk Maxwell Premium, IERE, U.K., for research on the detection of gravitational radiation (1972).
2. M. J. Buckingham, Royal Aerospace Establishment, A. B. Wood Medal, Institute of Acoustics, U.K. (1982)
3. M. J. Buckingham, Commendation for Distinguished Contributions to Ocean Acoustics at the Naval Research Laboratory, Washington D. C., U.S.A. (1984)
4. M. J. Buckingham, Alan Berman Publication Award from the Naval Research Laboratory, Washington D. C., U.S.A. (1988).
5. M. J. Buckingham, Scripps Institution of Oceanography, Science Writing Award for Professionals in Acoustics from the Acoustical Society of America (December 1997), for the article on "Seeing underwater with background noise", Scientific American, v. 274 (No. 2), 40-44 (1996).
6. M. J. Buckingham, Scripps Institution of Oceanography, Finalist, Discover Magazine Awards for Technological Innovation, June 1998 (Sight category) for pioneering acoustic daylight imaging.
7. M. J. Buckingham, Scripps Institution of Oceanography, Multiple entries in Marquis Who's Who and Strathmore's Who's Who.
8. M. J. Buckingham, Scripps Institution of Oceanography, Technical Program Chair of the 134th Meeting of the Acoustical Society of America, San Diego, California, 1-5 December 1997.
9. M. J. Buckingham, Scripps Institution of Oceanography, Technical Program Chair of the 148th Meeting of the Acoustical Society of America, San Diego, California, 15-19 November 2004.

My graduate students have been awarded six "best student paper" prizes by the Acoustical Society of America.

1. Thomas Berger, 1st Prize for "Low-frequency acoustic emissions of a plunging water jet. Part 1: experiment", 136th Meeting of the Acoustical Society of America, 12-16 October 1998.
2. Thomas Hahn, 3rd Prize for "Low-frequency acoustic emissions of a plunging water jet. Part 2: theory", 136th Meeting of the Acoustical Society of America, 12-16 October 1998.
3. Eric Giddens, 1st Prize for "Sound from a light aircraft for underwater acoustic applications",144th Meeting of the Acoustical Society of America, Cancun, Mexico, 2-6 December 2002.
4. Eric Giddens, 1st Prize for "Geoacoustic inversions in shallow water using Doppler-shifted modes from a moving source" 148th Meeting of the Acoustical Society of America, San Diego, California, 15-19 November 2004.

5. David Barclay, 1st Prize for "The effect of grain shape on the porosity of marine sediments", 154th meeting of the Acoustical Society of America, New Orleans, Louisiana, 27 November-1 December 2007.
6. David Barclay, 2nd Prize for "Doppler geo-spectroscopy in the Makai experiment", 155th meeting of the Acoustical Society of America, Paris, France, 29 June-4 July 2008.